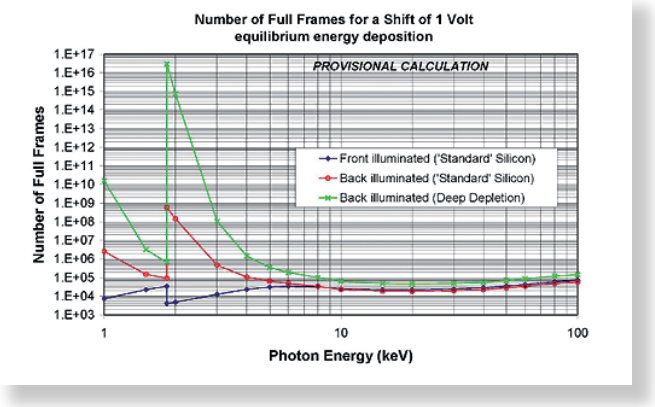
X-ray damage

CCD sensors are now routinely used for the direct detection of photons across the entire spectral range form NIR (1 µm) to X-ray (0.1 nm). Users should be aware, however, that in the X-ray spectral region, damage occurs and therefore CCD sensors have a limited lifetime when used for direct detection.

The interaction of highly energetic photons in the X-ray region produces permanent changes in the sensor, particularly in the vulnerable oxide layers surrounding the electrode structure. For low x-ray energies, back Illuminated advices are significantly more radiation resistant than their Front Illuminated equivalents as this oxide layer is somewhat protected form the incoming photons.



Direct Detection –X-ray Damage

X-ray damage manifests in four major ways:

- An increasing dark charge is observed with accumulated X-ray dose.
- The oxides become charged causing a shift in the ideal operating biases (voltage shift). This progressively compromises the performance of the sensors in charge handling capacity and in amplifier biasing. In AIMO (Asymmetric Inverted Mode Operation) devices this voltage shift will eventually take the device out of inverted mode operation with the associated significant increase in dark current.
- CTE (Clocking Transfer Efficiency) degradation for large signals.
- The formation of traps.

The increasing dark charge is the result of disruption to the silicon-gate interface. Since this surface component of the dark current is suppressed in AIMO or MPP (Multi Phase Pinned) devices, this type of X-ray damage is **not** significant in these sensors. It will however be present in NIMO (Non Inverted Mode Operation) sensors of which Deep Depletion sensors are probably the most interesting format. Due to this damage process, we recommend careful consideration before selection a NIMO sensor for an X-ray application.

The induced voltage shift can be corrected for, up to a point, but will ultimately limit the sensor's performance.

It is important to note that the damage occurring in a sensor is dependent on the processes used to manufacture that sensor. There is little comparison data between the manufactures. However, it is known that EV2's process is inherently more radiation resistant than Thomson's & SITe's LOCOS process.

Rule of thumb:

A 20 krad dose from 10 keV photons or 40 krad from 1 keV photons deposited in the gate oxides leads to a 1 V shift in the operation voltages. AIMO devices will start to come out of pinning after about a 1.5 Volt shift and a large increase in dark signal will be observed beyond this point. In the lifetime of the sensor, this shift can be corrected for by up to ~3 V (or equivalent to a 30 krad dose from 10 keV photons.